MEASUREMENT OF THE FLOW OF WATER
BY
SALINITY AND COLORATION METHODS
BY

J. P. BECHAUD
R. L. MORSE

ARMOUR INSTITUTE OF TECHNOLOGY
1917

621.2
M 83

Illinois Institute
of Technology
UNIVERSITY LIBRARIES

AT 461
Morse, R. L.
Measurement of the flow of
water by salinity and

Digitized by the Internet Archive
in 2009 with funding from
CARLI: Consortium of Academic and Research Libraries in Illinois

http://www.archive.org/details/measurementofflo00mors

Measurement of the Flow of Water by Salinity and Coloration Methods

A THESIS

PRESENTED BY

R. L. Morse and J. P. Bechaud

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

MAY 31, 1917

APPROVED:

Professor of Mechanical Engineering

Dean of Engineering Studies

Dean of Cultural Studies

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V. GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

INDEX PAGE

Object..... 1

References..... 2

Part 1. Salt Solution Method:

Method of Proceedure..... 3

Methods of determining weight of salt in discharge samples..... 3

Apparatus..... 5

Material used..... 9

Data..... 11

Sample calculations..... 18

Sources of error and corrections for future testing..... 20

Field testing..... 24

General discussion..... 26

Part 2. Coloration Method:

Description, and discussion..... 28

Illustrations:

Injection apparatus..... 8

Titration apparatus..... 7

27207

OBJECT

The object of this thesis is the measurement of the flow of water in pipes by the injection of a salt solution or colored solution.

REFERENCES:-

Groat,B.F.,Proceedings A.S.C.E. Dec.1916.

Miller,D.H.,Records American Water Works Association,1916.

Engineering News Record,May 3,1916,p.236.

PART 1.

Salt Solution Method.

Method of Proceedure:

An NaCl solution of known concentration is injected at a known rate into a pipe through which water is passing.

Two samples at a point along the pipe, beyond injection are drawn off. The first sample is drawn before injection and the other during injection.

The weight of salt per unit volume in the discharge samples is determined.

Knowing the dilution of the original solution and the rate of injection, the volume of water flowing can be determined.

1. By evaporation. A measured amount of solution is placed in a previously weighed evaporating dish and allowed to evaporate. The difference in the weights of the evaporating dish, before containing the solution and after evaporation is the weight of salt.

For accurate purposes, this method requires too much care and time.

Salt Solution Method.

2. By precipitation. A measured amount of solution is made to react chemically with $AgNO_3$. The resulting precipitate of AgCl is dried and weighed. By calculation the weight of salt can be determined.

This method requires the services of an expert chemist as well as consuming too much time.

3. By titration. A standard solution of $AgNO_3$ is made,which will precipitate a known weight of salt per c.c.

A measured volume of NaCl solution is completely precipitated by this standard $AgNO_3$. Complete precipitation is gained by the addition of a few drops of K_2CrO_4 which turns the solution red,when all of the salt is precipitated.

The product of the concentration of the standard $AgNO_3$ and the number of c.c. of $AgNO_3$ used determines the weight of salt per unit volume of solution.

Salt Solution Method.

This method is accurate,convenient, and quick,and consequently was adopted in the following salinity tests.

Apparatus:

The apparatus used in conducting the following salinity tests consisted of a supply of water,a pump,pipe line, injection apparatus, weighing tanks,and titration burette.

The water supply was taken from a sump, sunk into the laboratory floor. The approximate dimensions were 6 feet wide,14 feet long,and 6 feet in depth. The sump was provided with an overflow,situated about three inches from the floor level. A fresh water inlet,controlled by a valve,entered the sump at one end about 6" below the floor level. This source of water supply possessed the advantage of being at constant temperature,of being freshened when desired,and of being still water.

The pump used was a centrifugal one,of rated capacity of 75 gallons per minute.It was

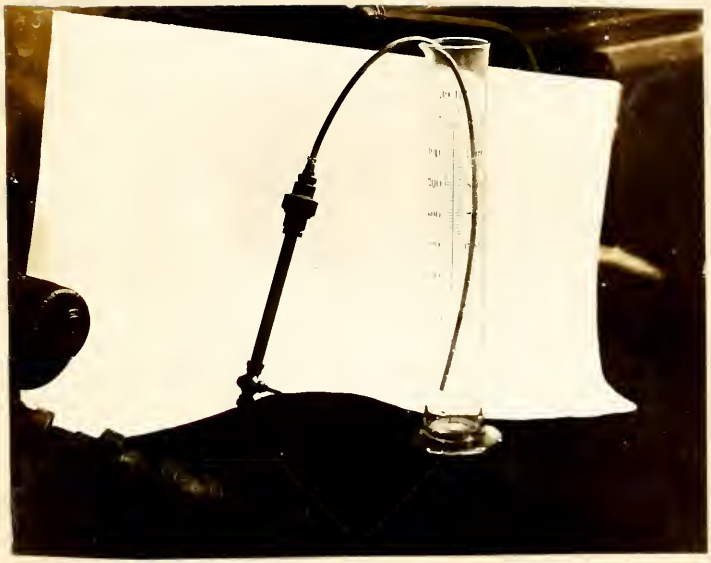
Salt Solution Method.

directly connected to a ¾ H.P. direct current motor with variable speed control. This combination of motor and centrifugal pump furnished a desirable impetus for water flow, because the impeller of the pump, in rotating, thoroughly mixed the injected salt solution. In addition the head of water could be quickly varied, and a constant head maintained between speed changes.

The pipe line through which the flow of water was measured was a 2" line, measuring about 20 feet in length overall. It extended from below the water level in the sump, up through the pump, then vertically upwards for about 6 feet, and then finally extending horizontally for about 8 feet, emptying into a weighing tank. The injection apparatus was tapped in about 12" before the entrance of the water into the pump. The diluted samples were taken off at the open end of the line.

The injection apparatus consisted of a 1/8" pipe tapped into the suction of the pump. Between the joints of a union in the section of

Titration Apparatus.



Injection Apparatus.

Salt Solution Method.

1/8" pipe was a brass disc with a small orifice drilled in the center. This disc was held firmly in place and made water tight by means of rubber gaskets on each side. The 1/8" line terminated in a rubber hose connecting it to the NaCl injection sample. This injection apparatus possessed the advantages of no pressure being needed to force the sample in and of a changeable surface.

The remainder of the apparatus used, ie., the weighing tanks, titration burette, etc., was standard laboratory apparatus.

Solutions used:

The NaCl solution injected was made up of common table salt and tap water. Its concentration was determined by titrating it against a standard $AgNO_3$ solution. A solution of high concentration was used, ie., approximately 3½ pounds NaCl per gallon.

The $AgNO_3$ solution used for titration purposes was prepared with chemically pure chemicals. Its strength was determined taking the

Salt Solution Method.

average number of c.c. required to precipitate a unit weight of salt.

The indicator used was K_2CrO_4. The approximate strength of $AgNO_3$ was .01 gr.NaCl solution precipitated by 1 c.c. $AgNO_3$.

Salt Solution Method.

Data From Salinity Tests.

Strength of NaCl solution;

407 gr. NaCl per 1000 c.c. solution.

Strength of $AgNO_3$ solution;

.0083 gr. NaCl precipitated per c.c.$AgNO_3$.

Time of Injection-1 minute.

Diameter of orifice-1/16" Temp. of water 60°F.

Run	c.c.NaCl solution injected	net no. c.c. $AgNO_3$ for titration.	calculated result	Actual result	% error
1	500	13.85	473	476	.6
2	490	14.60	439	474	7.5
3	480	13.45	464	453	2.4
4	470	13.40	458	451	1.5
5	460	13.40	418	428	2.3
6	405	13.45	377	361	4.4
7	355	15.10	307	299	2.7
8	275	13.55	266	241	10.3
9	110	3.52	372	434	14.2
10	465	14.61	416	460	9.6

Salt Solution Method.

Data From Salinity Tests.

Strength of NaCl solution;

407 gr. NaCl per 1000 c.c. solution.

Strength of $AgNO_3$ solution;

.0083 gr. NaCl precipitated per c.c.$AgNO_3$.

Time of injection-1 minute.

Diameter of orifice-1/16" Temp.water 60°F.

Run	c.c.NaCl solution injected	net no.c.c. $AgNO_3$ for titration.	calculated result	actual result	% error
11	455	15.00	397	417	4.8
12	405	15.70	337	359	6.3
13	285	17.25	216	241	10.3
14	355	18.95	245	293	16.4
15	380	17.50	284	350	18.8
16	440	14.25	404	414	2.4
17	385	13.40	341	354	3.7
18	350	14.70	311	294	5.8
19	440	14.15	406	418	2.9
20	325	16.85	252	252	0.0

Salt Solution Method.

Data From Salinity Tests.

Strength of NaCl solution;

407 gr. NaCl per 1000 c.c. solution.

Strength of $AgNO_3$ Solution;

.0083 gr.NaCl precipitated per c.c.$AgNO_3$.

Time of injection-1 minute.

Diameter of orifice 1/16" Temp.water 60°F.

Run	c.c.NaCl solution injected	net c.c. $AgNO_3$ for titration	calculated result	actual result	% error
21	320	16.98	246	252	2.4
22	370	17.35	279	299	6.7
23	380	12.80	389	402	3.0
24	455	16.05	371	306	7.7
25	340	14.10	313	344	2.3
26	325	13.50	326	418	5.8
27	415	13.08	414	418	0.7
28	420	14.70	375	402	10.3
29	425	14.65	380	407	6.6
30	430	14.80	380	403	6.6

Salt Solution Method.

Data From Salinity Tests.

Strength of NaCl solution;

222.7 gr. NaCl per 100 c.c. solution.

Strength of $AgNO_3$ solution;

.0133 gr. NaCl precipitated per c.c. $AgNO_3$.

Time of injection-1 minute.

Diameter of orifice-1/16" Temp. water 60°F.

Run	c.c.NaCl injected	net c.c. $AgNO_3$ for titration	calculated result	actual result	% error
31	565	9.55	437	439.5	0.569
32	560	9.22	448	439.5	2.05
33	540	9.30	429	439.5	2.27
34	545	10.15	398	439.5	9.45
35	550	10.08	403	439.5	8.30
36	515	9.58	397	408.5	3.30
37	520	9.10	422	408.5	3.45
38	515	9.10	417	408.5	2.03
39	520	9.35	410	408.5	0.36
40	540	10.04	383	408.5	6.09

Salt Solution Method.

Data From Salinity Tests.

Strength of NaCl solution;

222.7 gr. NaCl per 1000 c.c. solution.

Strength of $AgNO_3$ solution;

.0133 gr. NaCl precipitated per c.c.$AgNO_3$.

Time of injection-1 minute.

Diameter of orifice-1/16" Temp.water 60°F.

Run	c.c.NaCl injected	net c.c. $AgNO_3$ for titration	calculated results	actual results	% error
41	505	10.52	355	359	1.12
42	485	11.80	352	359	1.95
43	500	10.26	360	359	0.28
44	500	10.05	367	359	2.15
45	445	9.25	355	350	1.39
46	410	9.80	308	292.5	5.30
47	390	9.80	294	292.5	0.51
48	390	9.80	294	292.5	0.51
49	390	10.00	288	292.5	1.54
50	390	10.00	288	292.5	1.54

Salt Solution Method.

Data From Salinity Tests.

Strength of NaCl solution;

222.7 gr. NaCl per 1000 c.c. solution.

Strength of $AgNO_3$ solution;

.0133 gr. NaCl precipitated per c.c.$AgNO_3$.

Time of injection-1 minute

Diameter of orifice-1/16" and 3/32" Temp.water 60°F.

Run	c.c.NaCl injected	net c.c. $AgNO_3$ for titration	calculated results	actual results	% error
51	350	11.0	235	238	1.26
52	340	10.8	233	238	2.10
53	335	11.0	225	238	5.46
54	335	10.9	228	238	4.21
55	340	10.8	233	238	2.10
		Changed to 3/32" orifice.			
56	970	16.8	429	439.5	2.85
57	935	17.4	397	405	1.98
58	835	17.9	341	347	1.73
59	620	22.1	206	207	0.48
60	655	21.2	227	242.5	6.40

Salt Solution Method.

Data From Salinity Tests.

Strength of NaCl solution;

222.7 gr.NaCl per 1000 c.c. solution.

Strength of $AgNO_3$ solution;

.0133 gr. NaCl precipitated per c.c. $AgNO_3$.

Time of injection- 1 minute.

Diameter of orifice 3/32" Temp. water 60°F.

Run	c.c.NaCl solution injected	net c.c. $AgNO_3$ for titration	calculated results	actual results	% error
61	990	17.6	416	438	5.03
62	900	16.6	400	407	1.72
63	820	17.3	350	354	1.13
64	730	17.9	300	300	0.0
65	610	18.1	248	247	0.4
66	600	21.6	205	206	0.49
67	645	20.5	232	240	3.45
68	710	19.9	290	289.5	0.17
69	790	17.1	340	334.5	1.64
70	885	16.4	397	390.	1.79
71	1005	15.9	465	432	7.10

Salt Solution Method.

Sample Calculations.

Data Given:

Strength of salt solution = 406 gr. NaCl per liter solution.

Strength of $AgNO_3$ = .0083 gr. NaCl in solution precipitated by 1 c.c. $AgNO_3$.

Time of injection = 1 minute

No. c.c. NaCl solution injected = 500

Net no. c.c. $AgNO_3$ for titration = 13.85

Number c.c. in titration sample- 200

Weight of salt injected per second =

$$\frac{406}{1000} \times 500 \times \frac{1}{60} = 2.045 \text{ gr./sec.}$$

Weight of salt in 200 c.c. discharge sample =

13.85 x .0083 = .115 grams

Flow of water =

$$\frac{2.045 \times 200}{.115} = 3560 \text{ c.c.water per second,}$$

= 473 pounds of water per second.

The above can be reduced to a much simpler form, ie.,weight of water flowing per minute,

Salt Solution Method.

$$\frac{406 \times (a) \times 200 \times 60}{1000 \times 60 \times .0083 \times (b) \times 453}$$

where"a"is the amount NaCl solution injected per minute and"b"is the net number c.c. $AgNO_3$ required for titration.

Therefore,the weight of water flowing per minute is 13.09 x a/b.

The constant 13.09 can be used for all data taken,using 406 grams NaCl per liter,salt concentration,and $AgNO_3$ of such strength as to precipitate .0083 gr.NaCl per c.c. of $AgNO_3$.

If $AgNO_3$ and NaCl solution of different strengths are used,the constant will have to be refigured.

Salt Solution Method.

Sources of error and corrections for future testing.

The results of a large majority of runs indicate a percentage of error ranging from 0 to 6. The average percentage of error was about 2-½ %, and in nearly all cases the actual results exceeded the experimental results.

The probable cause for this constant difference between the calculated and actual results is in the fact that common table salt was used to make up the NaCl solution and also to standardize the $AgNO_3$. The percentage of impurities in common table salt is from ½ to 4 %. Consequently this impurity would cause an error in the calculations, making them always smaller than the actual result. Were it not for the "human element" this error might be properly corrected for by determining the percent of impurity in the salt used.

The human element accounts for the

Salt Solution Method.

variation in the percentage of error. Chances for the human element to play a part occur in every part of the test,ie., in titration,in weighing the water,in reading of the graduate for injection and in the taking of samples. Inasmuch as the injection was only of a moments duration and water was only weighed for one minute there was a possible chance of running over or under a second or two. Some of these chances for error are accumulative and some are corrective, but with so many places where the human element can insert itself, it is hardly possible to be sure of constant accuracy. The remedies for this chance of error are in the running of longer tests,and in the use of mechanical devices.

Another chance of error is the possible formation of an air-pocket in the injection apparatus due to leaky joints and to the tube,containing air before injection is started.

Considering the sources of error,just described, the obvious proceedure for future testing with the same apparatus is the elimination

Salt Solution Method.

of the human element and correction for the impurities in the NaCl solution used.

For future testing under the same conditions the following points may be profitably observed.

The injection and the weighing of water for purposes of checking calculated results, should be continued over longer periods of time. The magnitude of the error produced by the human element is constant and independent of time. Consequently an extension of time divides and decreases the percent of error.

A measured amount of NaCl should be injected and the time of starting and stopping injection taken by a stop-watch. This would eliminate the possibility of overtiming or undertiming injection.

A test for the percent of the impurity in a fair sample of the NaCl used, should be made by the

Salt Solution Method.

precipitation method. Knowing the percent of impurities in the salt, a correcting coefficient can be determined and applied to the test and calculations.

Salt Solution Method.

Field Testing: For conducting field tests the same method should be used.

The apparatus for injection in the majority of cases would have to be designed for injection against pressure. For low rates of injection a small double-acting hand pump,provided with an air chamber, could be used. For high rates of injection and where steam is available a small piston pump,provided with an air chamber and capable of exerting water pressure high enough to overcome that of the flow to be measured,could be used.In places where steam or other forces are not available,a pipe line, the height of which over the flow to be measured,is greater than the head of water caused by this flow could be used.In all of these methods a reservoir containing the injecting solution would be necessary and in order to determine the amount injected, the fall of the level in this solution in the reservoir would have to be noted.

The titration burette and the $AgNO_3$ should be carried to the scene of operation. This

will facilitate the quick operation of the test, and will make a saving of labor.

The injection solution should be made up at the scene of the test.The strength of it can be determined by titration against a standard $AgNO_3$ which would have to be brought along.

Each field test would be a problem in itself and consequently only very general suggestions can be given.

Salt Solution Method.

General discussion: The results of the tests taken indicate that the salinity method can be used to measure water with a fair degree of accuracy.The method in its present state of development is not a practical method for measuring small water flows,when compared to the numerous water meters and Venturi meters on the market.

For large and turbulent flows,the method is perhaps the only method for measuring the flow with accuracy. An example of the successful application of the salinity method is in hydro-electric water turbine testing. To carry on tests of such a large nature requires immense quantities of NaCl solution and a differently designed injection apparatus. The problem confronted with each test is a problem by itself, and must be dealt with accordingly. Although the method of calculating the water flow from the acquired data is essentially the same in all cases.

Salt Solution Method.

A further development of the salinity test in connection with small flows should be along practical lines with the view of correcting or eliminating all sources of error. It is possible with proper srudy to develop a recording meter, operating upon the salinity principle.

Part "2".

The Coloration Method.

The proceedure followed using the coloration method is practically the same as that followed, using the salinity method. The injected solution, instead of being an NaCl solution would be a colored solution, whose color is dependent upon its concentration. The concentration of the injected solution would of course be known. The concentration of the diluted samples drawn off would be determined by comparison with standard sample of known concentration. The coloration method thus followed has the advantage of eliminating titration necessary in the salinity method and consequently reducing the time and knowledge necessary for testing

The standard samples are made up of solutions of gradually increasing concentration. The samples are placed in test tubes, filling them to a measured depth. Their color is noted by glancing vertically into the test tube. The color

The Coloration Method.

of the diluted sample drawn off is noted in the same way and by matching it with one of the standard samples, its concentration can be determined. Knowing the concentration of the two samples and the rate of injection, the water flow can be determined.

This method was abandoned because of lack of time and facilities necessary. The sources of water supply used in connection with the salinity test could not be used continuously because it soon attained color and made the matching of samples harder. The coloration method, however, shows promise and has the advantage over the salinity method of simplicity and quickness.